STUDIES UPON THE CEREBRAL CORTEX IN THE NORMAL HUMAN BRAIN AND IN DEMENTIA PARALYTICA.

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Several neuroglia cells as at N, rounded or oval in shape, are to be seen here also interspersed among the nerve cells, and they increase in number proportionate to the nerve cell decrease as the white medullary center is reached. Several capillary blood vessels are to be seen in this layer, cut in different planes. Their walls are made up of a single layer of thin nucleated cells and the vessels filled with red blood corpuscles. The cells of this layer belong to the somatochrome class and either the archyochrome or gryochrome group, depending on whether one regards the chromatic substance as making up a distinct network as in the archyochrome group or as small granules arranged in threads or heaps as in the gryochrome group. It is difficult to determine a network of any distinctness in the majority of these cells, and they seem to the writer to belong more to the gryochrome group. The entire cortex thus measures in this section approximately 2.85 mm. in thickness as it is really an arbitrary division to state just where the gray cortex ends and the subcortical white medullary substance begins, there being a gradual transition from the one to other here as well as between the layers of the cortex. In order to obtain the approximate number and ratio of the nerve cells to the neuroglia cells an effort was made to count the same in various sections of the photomicrograph, counting the nerve cells first and marking each one as counted by black ink, and afterwards doing the same for the neuroglia cells. Upon subsequently using a Zeiss ocular micrometer divided into millimeter squares in a No. 3 ocular with a No. 6 objective, thus giving a magnification of 390 diameters, it was found that the former method, in which only a magnification of 100 diameters was used did not show all the structures present, and those shown were not sufficiently distinct at times to determine accurately their real nature, whether neuroglia cells, portions of nerve cells, etc. With the above magnification,—390 diameters,—and upon focussing in various planes, it was found for instance that a single mass upon the photomicrograph could be resolved into two or more neuroglia cells close to one another and in slightly different planes. By using the above combination it was found that one side of the millimeter square in the eye-piece corresponded to .033 mm. of the stage micrometer and thus of the surface of the section under observation, so that a square millimeter of the ocular network was therefore equivalent to .033^{2}3, or .00999 square millimeters (practically .01 square millimeters, which latter decimal was used for convenience in this work) of surface of the section under examination. The ocular micrometer was divided into 36 squares and the number of nerve cells in each of these squares was counted and recorded in seven different fields, in this case in different parts of the section, thus making 252 squares in all. The result was added up and divided by 252 in order to give the average number of nerve cells for each square. This number was equivalent to that contained in .01 sq. mm. of actual surface of the section, or practically 1-100 of a square mm. The total number of neuroglia cells in 108 squares from three different fields was determined in the same manner, the resulting total being divided by 108 to give the average number of neuroglia cells for each sq. mm. of the ocular net-micrometer or .01 sq. mm. of actual surface of the section. These results multiplied by 100 thus will give the number of nerve and neuroglia cells for each square millimeter of actual surface of the section. With this method the average number of nerve cells to each sq. mm. of the ocular net-micrometer was found to be 1.1685; multiplied by 100 gives 116.85 as the average number of nerve cells to be found in each sq. mm. of this section in the second and third layers. In the region just below the middle of the second layer previously described as made up almost exclusively of small pyramidal cells these latter are found very densely packed together, in many parts as many as 2.7 cells were found to each square on an average. This result multiplied by 100 as before gives the high average of 270 nerve cells to each square millimeter in this narrow region, whereas the general average for the entire second and third layer, not including this region, is but 93 nerve cells to the sq. mm., thus showing the great variation in regions of the same section closely approximating one another. The nerve cells of the first layer were so few and scattered that they were not included in this count. In the same way the average number of neuroglia cells to the square millimeter of surface of the section was found to be 125. Counts were also made from a section from the first frontal convolution, somewhat anterior to that from which Plate II, Fig. 3, was taken. This latter block was hardened in alcohol, the section was 10 microns in thickness, and similarly stained with methylene blue. Decolorization was not carried on to such an extent, so that the neuroglia cells were not decolorized, and the section being 10 microns in thickness in comparison to 6 2-3 microns in Plate II, Fig. 3, the neuroglia cells were found to be more numerous. This would seem to indicate that fixing in Van Gehuchten's fluid and staining the same length of time in warm methylene blue results in a somewhat greater decolorization of the neuroglia cells in the following differentiation than in sections hardened in alcohol and treated similarly in respect to staining and differentiation. As stated this section was 10 microns in thickness, whereas that of Plate II, Fig. 3 is but 6 2-3 microns in thickness; but it will be seen by the following figures that whereas there is only a slightly greater number of nerve cells in the former as compared to the latter the neuroglia cells are considerably in excess in the former. Here counts were made in seven different fields of 36 squares each in various parts of the second and third layers for the nerve cells, and in all three layers for the neuroglia cells. The average number of nerve cells was found to be 1.27 to each sq. mm. of the ocular net-micrometer, which multiplied by 100 gives 127 as the average number of nerve cells to the sq. mm. of surface of the section. In the same way the average number of nuroglia cells was found to be 1.64 to the square millimeter of the ocular net-micrometer, which again multiplied by 100 gives 164, as the average number of neuroglia cells to each sq. mm. of surface of the section. The difference in the number of nerve cells in the two sections is not very great,—about 10 per cent, but in the number of neuroglia cells it is much more marked,—over 30 per cent, due partly to the difference in thickness and partly to the greater decolorization of the first section described (Table II). Hammarberg (1895) for counting nerve cells, and Popoff (1894) for determining the ratio of increase in neuroglia cells in acute and chronic cases of Asiatic cholera, used the ocular net-micrometer in a manner similar to that made use of in this article, but in each case in a different line of investigation; the former in the study of idiocy, and the latter, as already stated, in Asiatic cholera. The number of nerve cells and of neuroglia cells, as well as their ratio to one another, varies in the different layers of the cortex. In the first layer there are but few nerve cells, whereas the nuroglia cells are about the same or even more in number than in the other layers, thus making a high ratio. In the second and third layers, however, the cells are the important elements and occupy the greatest amount of space, and although fewer numerically than the neuloglia cells the latter are much smaller, less conspicuous, and the ratio is not so great. Then again the cells are not evenly distributed, but have a tendency to be arranged more or less in irregular groups, so that in some places they are relatively widely scattered, whereas in others they are more closely aggregated, so that a number of counts in various parts of the field are necessary to get an approximate average of the number of cells. The thickness of the section, degree of staining, and extent of differentiation or decolorization must also be considered in Nissl work, as too great decolorization will prevent some cells from being recorded in a photomicrograph, and an extremely thin section would not contain as many cells as a thicker one. Sections 6 2-3 and 10 microns in thickness (two and three clicks of the Minot microtome) were used in this work, and when well stained and decolorization is not carried too far, will show all cells to be found in such a plane.

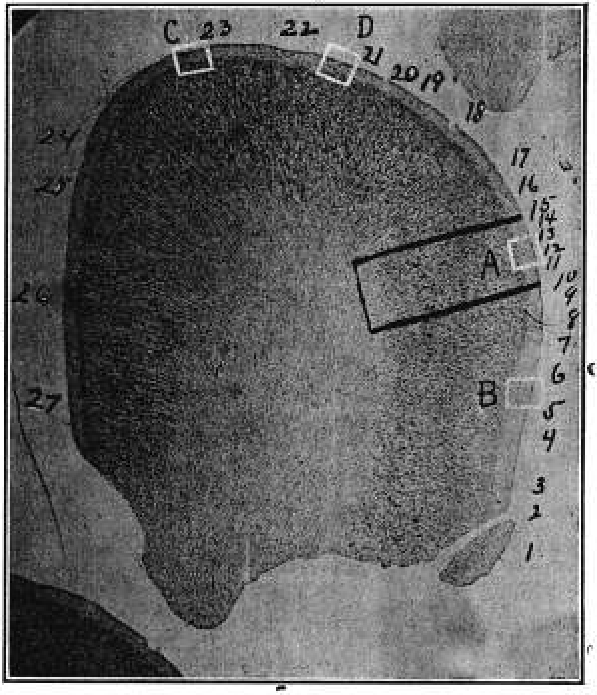

Plate III, Fig. 7.

Central Region Turning now to the region posterior to this we come to the motor region of the cortex, comprising the anterior and posterior central convolutions. This region is of especial interest in many ways, and has probably been more extensively studied than any other of the various regions of the cortex. Plate III, Fig. 7, is a photomicrograph magnified 14 diameters, taken from a section 10 microns in thickness at the upper third of the anterior central convolution of Brain A. (Plate I, Fig. 1, 2.) This block was also fixed in Van Gehuchten's fluid, imbedded in paraffin and sectioned serially by a Minot microtome. This section was then stained with warm methylene violet, differentiated in alcohols, 30, 50, 70 and 95 per cent., and absolute, cleared in xylol and mounted in xylol-damar. The actual size of the section which includes the entire width of the gyrus, is .7 of a c. m. in width by .7 c. m. in depth, and taken from a block .4 cm. in thickness, the plane of the section being at right angles to the direction of the gyrus. At the point *a* and outlined in ink is the strip seen in Plate III, Fig. 8, at a magnification of 100 diameters. The outer layer of the cortex is seen to be fairly uniform in thickness, with the exception of the regions indicated at *b* and *c*. At *b* this layer is considerably thicker than in any other part, gradually diminishing in thickness near *a* where it is of the average thickness. At the point *c* is seen a slight thinning of the cortex, which in Plate IV, Fig. 9, results in the entire disappearance of this layer and is intermediate in degree in Plate IV, Fig. 11. This condition will be more fully discussed in the description of these latter plates, and it will be simply stated now that this is an artefact probably due to manipulation. The general radiating appearance of the cortex from the white medullary center to the periphery is well seen here. In the region of the lower part of the second or middle cortical layer even with this low magnification can be distinctly seen the giant pyramidal, or Betz cells arranged singly or in groups. Below this the cortex becomes paler and finally merges into the central medullated white substance. This magnification is especially good for studying the arrangement of the Betz cells. Beginning with the first group in the lowest part of the section on the right, which is the posterior surface of the gyrus, opposite 1 is a single Betz cell of moderate size; just above this, opposite 2 is a group of two Betz cells, one nearer the surface and above the other in the lower part of the second or pyramidal cell layer. Somewhat higher up, opposite 3, and somewhat deeper, are seen two very large Betz cells, one deeper and further from the surface, as well as higher up than the other. Opposite 4 are three Betz cells too far separated to be considered as a single group, so must be regarded as solitary cells. Just above them at 5 are three smaller cells, one above the other at about the same depth of the cortex. Opposite 6 are two small Betz cells, one nearer the surface than the other. Then for a considerable distance no Betz cells are to be seen until we reach a point opposite 7 where a fair sized solitary cell is made out. Just above this opposite 8 are two rather small Betz cells, and a short distance above at 9 a group of three containing two large and one small Betz cell. Opposite 10, and just below the lower ink mark are two very large Betz cells, one overlapping the other, giving the appearance of one in the plate. Just above the ink line opposite 11 is to be seen a group of four Betz cells, one large, and the other three smaller. These and those above and included between the two parallel ink lines can be seen at a magnification of 100 diameters in Plate III, Fig. 8, this group being on the extreme right of the latter. Opposite 12 is a group of four Betz cells arranged radially, the upper of the two in the middle being the largest, and the lowest next in size. Opposite 13 is a large solitary Betz cell, and above this and opposite 14 is a group of three Betz cells. Opposite 15 is another large solitary Betz cell, below which, and a little deeper in the cortex between it and the previously described group, is another Betz cell of medium size. Just above this is a group of two smaller Betz cells. Opposite 16 are three large cells in a group which are just to the left of Plate III, Fig. 8, and are intermediate in type between the well defined Betz cells and the ordinary large pyramidal cells, above this and opposite 17 is another group of four cells similar in type. Opposite 18 is a group of two Betz cells, one considerably larger than the other and nearer the surface of the cortex; in the same radial line is a medium sized solitary Betz cell. Just above this are five Betz cells opposite 19 and radially arranged in a row. Opposite 20 is a solitary Betz cell, and just above opposite 21 is a group of two Betz cells, one very large and the other quite small. Above this (to the left) are a number of pyramidal cells scarcely large enough to be considered as Betz cells, although as previously noted there are intermediate forms which might be considered as very small Betz cells or very large pyramidal cells. Opposite 22 are seen three Betz cells rather scattered, the one in the middle being at a deeper level of the cortex. Opposite 23 is seen a small solitary Betz cell, and opposite 24 is another solitary Betz cell. which is on the anterior aspect of the gyrus. Between it and the last described cell are quite a number of large cells intermediate in type between the Betz cell and the largest pyramidal cells. Opposite 25 is still another solitary Betz cell. Then comes a region for a considerable distance in which are seen several large cells at this level, but hardly large enough to be considered as Betz cells until we reach that part of the cortex on the anterior aspect of the convolution opposite 26, where we see a group of two made up of a large Betz cell and a smaller one. Finally below this, at a considerable distance and opposite 27, is a group of three Betz cells, the one in the middle being large, and the other two small. It will be seen that the Betz cells are larger and more numerous on the posterior aspect of the gyrus than upon the anterior aspect. There are thirty-one groups of these cells in all, 13 of which contain but a solitary cell, so can hardly be considered as a group, though of course many of them form part of a group, the remaining cells being in another plane. Ten of these groups contain two cells each, 5 cells each, and but two groups have four cells each, and one group has five cells, making 61 Betz cells in all in this section. Beginning posteriorly and following around to the lowest group on the anterior surface, the number of cells in each group as seen in the same plane is as follows:—1, 2, 2, 1, 1, 1, 3, 2, 1, 2, 3, 2, 4, 4, 1, 3, 1, 1, 2, 2, 2, 1, 5, 1, 2, 3, 1, 1, 1, 2 and 3. These cells lie deeper in the cortex and thus at a greater distance from the surface in the posterior aspect of the gyrus than at the vertex or at the anterior aspect. Of course the number of cells in this one plane does not represent in every case all the cells in a group, but only those in this particular plane. As many of these groups are more or less spherical no one plane will show more than a part of such a group, and as stated above some of these solitary cells are the outer members of some of these groups.

Plate III, Fig. 8, as previously stated, shows the strip *a* of Plate III, Fig. 7, under a magnification of 100 diameters and in strong contrast to Plate II, Fig. 3, is to be seen the much larger number of neuroglia cells, the methylene violet stain seeming to have a stronger affinity for the neuroglia cells than the methylene blue stain. The cortex in this plate is also seen to be more condensed and not so deep as in Plate II, Fig. 3. The first layer measure but .20 mm. in thickness in contrast to .25 mm. in the above mentioned plate. In this layer neuroglia cells are more numerous, with a few scarcely scattered nerve cells only to be made out under high magnification, and similar to those found in the first layer in Plate II, Fig. 3. The second or pyramidal cell layer is of special importance and interest. It is deeper than the corresponding layer in Plate II, Fig. 3, measuring 1.75 mm. in thickness as contrasted to 1.40 mm. in the former. Here too in addition to the large and small pyramidal cells are found the giant pyramidal or Betz cells, irregularly distributed, singly or in groups, and at different levels, so that it is impossible to describe them as forming a distinct layer, although in this plate, with the exception of one cell, at *a* they appear to be placed in the lower part of this portion of the cortex now being described. In taking one section after another, however, it will be found that these cells are located at different levels, the majority being in the lower portion of this second layer. They furthermore have a tendency to be arranged in groups containing from two to ten cells, rarely more, and finally we find some sections containing no Betz cells at all. The pyramidal cells in the motor area are found to be larger in size on an average than those of the frontal region. The chromatic substance is not arranged in such large distinct bodies as in the Betz cells, but may be seen distributed in clumps of finer or coarser granules in different parts of the cell-body, especially about the nucleus and about the base, and at the beginning of the dendritic processes in the cell-body. Fig. M (M, of Plate III, Fig. 8), shows one of these cells under a high power, X1300 (No. 3, ocular, 1-12 inch oil immersion objective. Leitz). Here the finely granular chromatic substance is distributed in a ring about the nucleus, a clump is seen at the base to the left where a dendritic process is given off and also clumps are seen at the base of the dendritic process on the right and other clumps in the upper part of the cell-body and in the apical process. In addition to this, small sized linear and rounded chromophilic bodies are seen in the upper part of the cell-body and apical process and also in the dendritic processes given off at the base. The nucleus here is large, rounded, centrally placed, and contains a round, deeply stained, prominent nucleolus, surrounded by slightly stained homogeneous nuclear substance. In some cells the finely granular chromatic substance predominates in the cell-body, while in others the small chromophilic bodies are more prominent, whereas the majority contain both, as in the above described cell. In some of the smaller pyramidal cells the large nucleus almost fills up the cell-body, with but a narrow rim of finely granular chromatic substance surrounding the same and extending into the apical and basal processes. These latter cells would be classified under the group of karyochrome nerve cells; whereas the larger pyramidal cells with the stainable substance arranged in striæ in the same direction as the contour of the cell-body come under the head of the stichochrome nerve cells of the somatochrome class. Turning to the Betz cells and examining these under a high power (No. 3 ocular 1-12 inch oil immersion objective, Leitz. X1300) they are seen to contain numerous distinct chromophilic bodies varying in size and shape. In Fig. N (N, of Plate III, Fig. 8) the upper part of the cell is not included in this section. From below are seen two dendritic processes given off from the under side of the cell-body, that is having the cell-body from a lower plane than figured in the drawing, upon the right side; and one slightly larger process from the left side. These at intervals contain distinct chromophilic granules, for the most part linear in shape, with the long axis parallel to the axis of the process and extending for a considerable distance into the process—as far as they could be traced in the section. About the middle of the left dendritic process is seen a large irregular chromophilic body at a point where a branch is probably given off, as wedge-shaped chromatic masses are often found at the point of branching of a dendritic process, Nissl's so-called "wedges of division." Within the cell-body the granules are seen to be elongated, rounded or irregular in shape, the first mentioned predominating; some much larger than others, and with the general arrangement of the long axis parallel to the sides of the cell-body. The nucleus is large, well defined, and placed in the upper part of the cell-body and nearer the right than the left side. There is a well defined, deeply stained nucleolus centrally placed and surrounded by a homogeneous, slightly colored nuclear substance, with no well defined network. At the base of the cell-body, occupying a space somewhat larger than the cell nucleus is a deposit of yellowish pigment, elliptical in outline, and entirely displacing all other cell contents. No other pigment is to be found in this cell. The arrangement of the chromophilic granules in striæ in the same direction as the contour of the cell-body classifies it as a stichochrome nerve cell of the somatochrome class. Fig. o (o of Plate III, Fig. 8) shows another of these Betz cells examined under the same magnification of 1,300 diameters (No. 3 ocular, 1-12 in oil immersion lens, Leitz), in which the arrangement of the chromophilic bodies in striæ parallel to the contour of the cell-body is very well marked. This arrangement extends far out in the basal process and high up in the apical process. The nucleus is situated more on one side of the cell-body than the other, and the nucleolus is not included in this plane. There are three dendritic processes to be seen, the apical extending for a considerable distance towards the periphery, and gradually decreasing in size, and two basal processes, the one to the left unbranched, while the one on the right gives off a large branch shortly after leaving the cell-body, at which point *a* is one of the so-called "wedges of division" of Nissl. There is no pigment in this cell, but in the one seen just below this in Plate III, Fig. 8, marked P, a large mass of yellow pigment is seen above and to one side of the nucleus at the base of the apical process. There are but few chromophilic bodies in this cell compared to the two previously described, the chromatin being for the most part in the form of fine granules arranged in larger and smaller masses in different parts of the cell. The Betz cell seen lying just below and to the right of this latter, and marked Q in Plate III, Fig. 8, also contains a small mass of pigment poorly defined, and lying just below the nucleus at the base of the cell. The other Betz cells seen in this plate contain no pigment. While discussing the Betz cells, and before proceeding to the description of the third layer, several other photomicrographs will be described as illustrating the grouping and structure of these cells. The first of these, Plate IV, Fig. 9, is a photomicrograph magnified 14 diameters of a section in close proximity to that seen in Plate III, Fig. 7, of the same size as this latter and treated in the same way, excepting that methylene blue was used as the stain here. Opposite *a*, and enclosed in ink lines, is the segment of the section shown in Plate IV, Fig. 10, under a magnification of 100 diameters. The other layer is seen to vary in thickness, being much thicker at the posterior aspect, at *b*, than at the vertex or the anterior aspect.

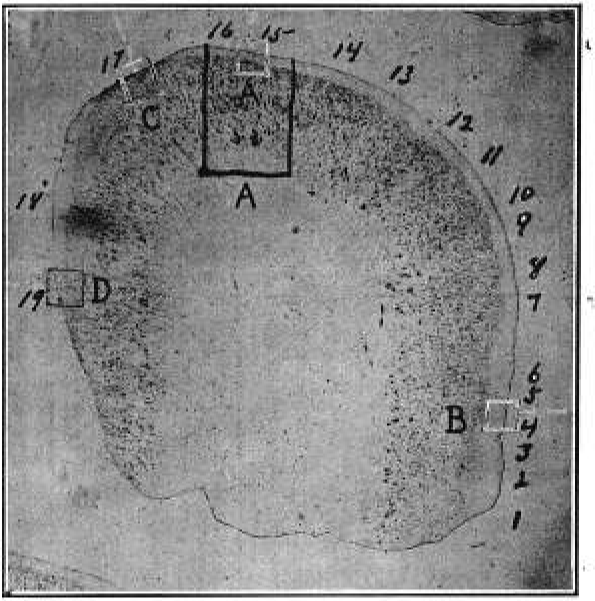

Fig. J.

At *c* and *d* the second layer is seen at the surface, due no doubt to injury in manipulation, probably more from pressure than actual tearing, as the surface is smooth and continuous at both ends, with the adjacent surfaces. No doubt artefacts similar to this, and of greater or less extent, must be carefully guarded against and considered in all work upon such a delicate and yielding tissue as the brain, especially when secured within a few minutes after death, as in this case, and before any post-mortem fixity results. The second layer shows the radial arrangement of the cells, but the most conspicuous feature is the distribution and arrangement of the Betz cells contained in the lower part of this layer singly or in groups of varying number and size. Below this the less conspicuous third layer is gradually lost to view as it merges into the white medullary substance. The arrangement of the Betz cells will be described in detail as photomicrographs of this magnification, 14 diameters, show their distribution especially well. Beginning at the posterior portion of the convolution below the letter *b*, the first large Betz cell is to be seen opposite the figure 1, and is solitary, whereas just above and opposite 2, is a group of four Betz cells all of about the same depth of the cortex. Above this, opposite 3, is a large solitary Betz cell. Opposite 4 is a group of three cells arranged radially above one another. Opposite 5 is another solitary Betz cell. Above it a small portion of a Betz cell is seen which lies mostly in another plane, while below it small portions of three Betz cells are seen lying for the most part in another plane. Above this, and opposite 6, is a group of two Betz cells at the same depth, and one just above the other. Between 6 and 7 are seen cells, two in number, which might be regarded as intermediate in character between the large pyramidal and Betz cells, having a similar arrangement of chromophilic substance, but of intermediate size. Opposite 7 is a group of two Betz cells, and opposite 8 is another group of two Betz cells somewhat nearer the surface, and just under this latter group and deeper in the cortex is a solitary Betz cell. Opposite 9 is a group of two Betz cells, only a very small portion of the upper cell being seen in this plane. Opposite 10, a portion of a solitary Betz cell is seen, and opposite 11 is still another solitary Betz cell. Opposite 12 is a group of three Betz cells, and just to the right of this and at the same level, is a part of a solitary Betz cell, while nearer to the surface and in the same radial line is still another small solitary Betz cell. Opposite 13 is a group of six Betz cells, two of which are large, and appear very prominently, the other four lying somewhat to the right, being smaller, but having the characteristic structure of the Betz cells. Opposite 14 is a solitary Betz cell, and next we come to the two groups seen under a magnification of 100 diameters in Plate IV, Fig. 10, and in this plate seen enclosed in ink lines and opposite figures 15 and 16. The first group, or that opposite 15, contains nine well defined Betz cells, while the adjacent group, opposite 16, contains six Betz cells, three large cells and the segments of three others, the greater part of these latter lying in another plane. Opposite 17 are four scattered cells at about the same depth of the cortex, and intermediate in size and structure, between the large pyramidal and the Betz cells. Opposite 18 is a large solitary Betz cell, above and below it being the cells intermediate in type just described. At 19 is a group of six, made up of one large Betz cell and five smaller ones about it. Above and below this are other pyramidal cells at this level, and of the above described intermediate type. There are in all fifty-nine of these Betz cells in this section, arranged singly or in groups; beginning posteriorly at 1, and proceeding around to the anterior and last group at 19, as follows: 1, 4, 1, 3, 1, 1, 3, 2, 2, 2, 1, 2, 1, 1, 3, 1, 1, 6, 1, 9, 6, 1 and 6, thus making twenty-three groups in all, eleven of which contain solitary cells, four contain two cells, three

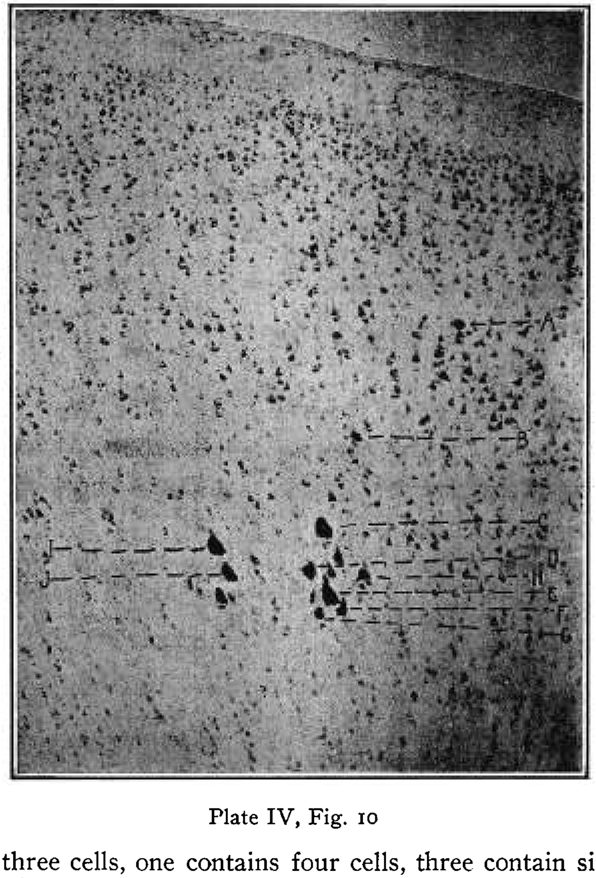

Plate IV, Fig. 10

contain three cells, one contains four cells, three contain six cells, and one nine cells, in the plane of this section. Of these cells thirty contain distinct pigmentary deposits, these being practically all of the larger cells. Quite a number of the others in the plane of the main portion of the cell would undoubtedly also contain pigmentary deposits. The grouping, of course, is here described for only the plane of this section and the probability is that some at least of these solitary cells are a part of a group,, the remaining cells lying in another plane. Furthermore, some of the groups described may contain additional cells lying in the plane above and below that of this section. Plate IV. Fig. 10, previously mentioned, has a magnification of 100 diameters, and includes the strip *a* outlined in ink in Plate IV. Fig. 9. Two groups of Betz cells are seen, one containing nine and the other six cells. Two other cells, *a* and *b*, though smaller yet in structure approach in character the Betz cells. It will be noticed that the cortex is not so deep in this plate, the first layer being but .175 mm. in thickness, and the second but 1.20 mm. in thickness in comparison to .20 and 1.75 mm., respectively, in Plate III. Fig. 8. It will be noted, however, that this strip was taken from the vertex of the section where the cortex is not so deep as on the posterior aspect from which Plate III. Fig. 8 was taken. These two groups of Betz cells are but 1.20 mm. from the surface of the cortex here in contrast to 1.70 mm. in Plate III. Fig. 8, showing the variability in thickness of the cortex in close proximity, as both plates were made from

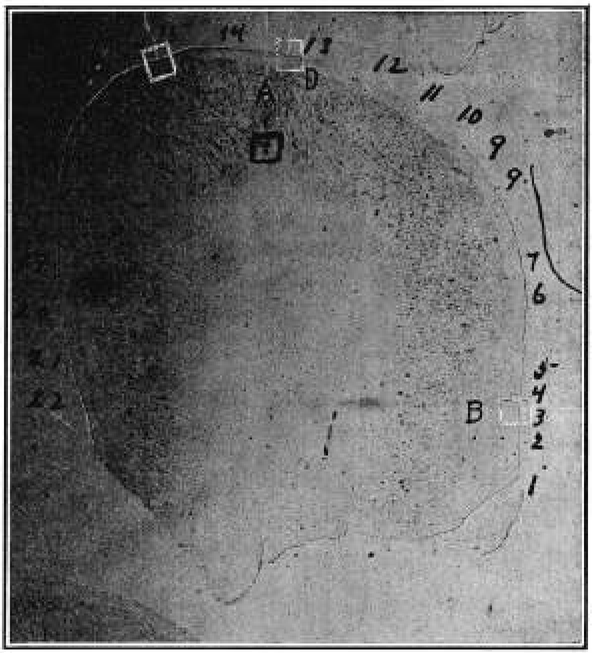

Plate IV, Fig. 11

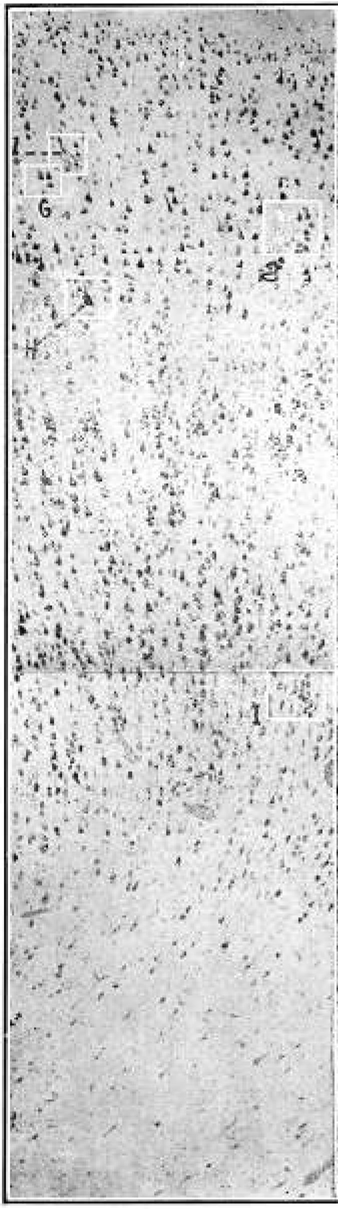

Plate II, Fig. 3.

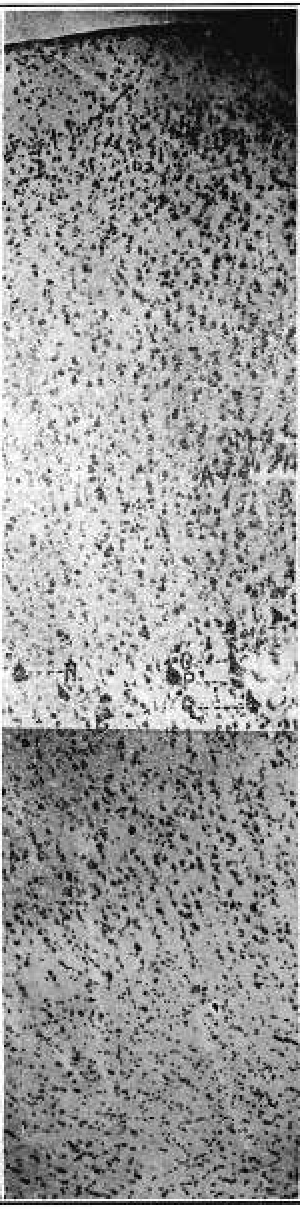

Plate III, Fig. 8.

Plate VI, Fig. 17.

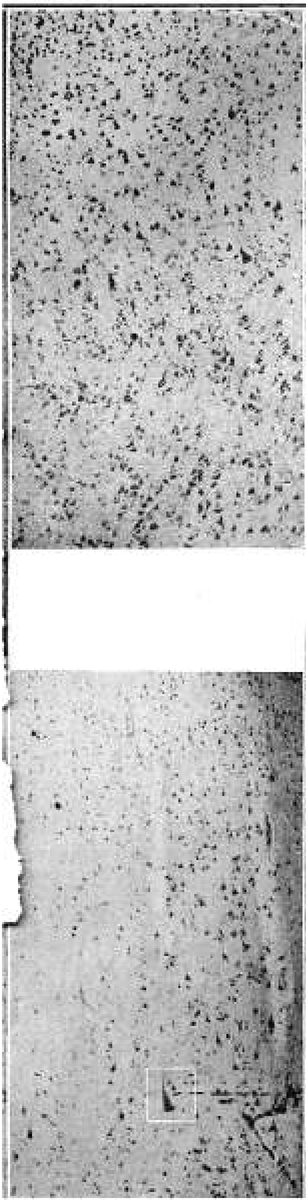

Plate VII, Fig. 19.
Plate XIII, Fig. 41.

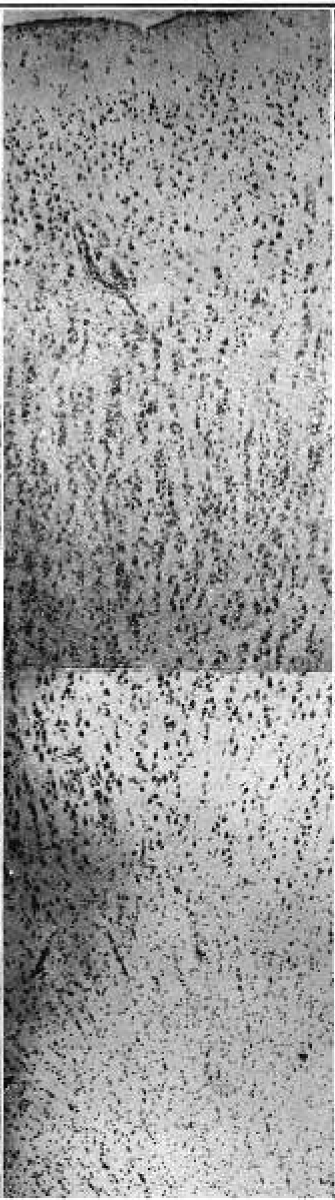

Plate VII, Fig. 21.

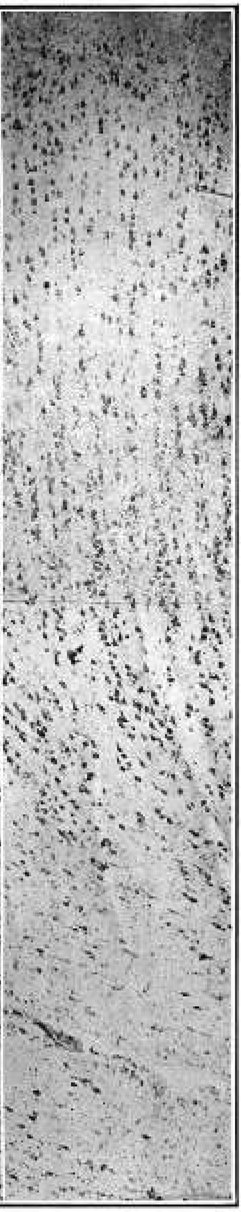

Plate VIII, Fig. 23.

sections cut from the same block which was not more than half a centimeter in thickness. The Betz cells here have the same structural characteristics as those described in Plate III. Fig. 8, and five of the cells, marked *c, d, e, f,* and *g,* of the larger group, and two of the cells, marked *i* and *j,* of the smaller group, contain distinct yellowish pigment. The larger of the two groups and containing nine Betz cells is made up of two very large cells cut in the plane of the nucleus, four smaller cells also cut in the plane of the nucleus, while the remaining three cells show only a small portion of the body of each cell here, the large portion of these latter being in another plane. Five of these nine cells contain deposits of pigment, and all show the chromophilic granules, being seen especially well in the cells marked *c, d, e,* and *h.* The cells in this group are quite close to one another and do not take up a very large space. The smaller group to the left contains six Betz cells, three large and conspicuous, and three others, one to the right and two to the left of these large cells which lie only partially in this plane and are small in size. Two of the three large cells marked *i* and *j* contain deposits of yellowish pigment at the base of the body of the cell, and all contain well defined chromophilic bodies. Plate IV. Fig. 11 is another photomicrograph of a section from the same block as that from which the sections represented in Plate III. Fig. 7, and Plate IV. Fig. 9, were taken. This section is 10 microns in thickness, stained with methylene blue and otherwise similarly treated as the above mentioned plates. This magnification of 14 diameters shows the outer layer to be fairly uniform in thickness, excepting at the points *b* and *c.* At *b* it is of relatively the same thickness as at the same point *b* in Plate IV. Fig. 9, about one and one-half times as thick as at *d* into which it gradually merges. At *c* where no outer layer is to be seen in Plate IV. Fig. 9, here the outer layer is distinctly seen but somewhat thinner than on either side, showing the artefact to be less in degree in this section. At *a* the group of cells represented in Plate V. Fig. 13, is seen, and each cell can easily be distinguished and counted under this magnification of 14 diameters. The second layer here is also especially interesting in respect to the size, number and distribution of the Betz cells singly or in groups in the lower portion of the layer near the transition into the third or spindle cell layer. This latter is less distinct and lost below in the medullary white substance in the interior of the gyrus. A detailed description of the arrangement of these Betz cells will be given in order to compare the same with those of Plate III. Fig. 7, and Plate IV. Fig. 9. Beginning with the first group at the lowest part of the section on the right, which is the posterior surface of the gyrus, opposite I, is seen a group of three large Betz cells. Above this some distance opposite 2, is a solitary Betz cell. Opposite 3, is another group of three Betz cells at a slightly greater depth. Above this and opposite 4 and 5, respectively, are large solitary Betz cells. Then there is a considerable interval where there are a number of large pyramidal cells but scarcely approaching the size of a Betz cell until the point opposite 6 is reached where a large solitary Betz cell is seen and just above it a group of two Betz cells somewhat smaller in size is to be noted. Opposite 7 is a solitary Betz cell at a greater depth. Just above this and slightly nearer the surface are several intermediate type cells arranged in two rows, one at a slightly greater depth than the other. Opposite 8 and at the same level as the preceding is a solitary Betz cell, and above this opposite 9 is a larger solitary Betz cell. At the same depth and slightly nearer the vertex is a group of two Betz cells, one large and the other small. About midway between these and the surface of the cortex are seen several very large pyramidal cells, the so-called intermediate type between the Betz cells or giant pyramidal cells and the ordinary sized large pyramidal cells. Opposite 10 is seen a group of two very large Betz cells just below and to one side of a large blood vessel. Just above this and nearer the surface is a small solitary Betz cell. Opposite 11 are three groups of Betz cells, the first containing three, the second two, and the third above and nearer the surface consisting of a large solitary Betz cell. Opposite 12 is a large solitary Betz cell, considerably nearer the surface than the groups just described. A group of two large Betz cells, one just above the other, is seen opposite 13. This brings us to the large group opposite *a* and seen under a magnification of 850 diameters in Plate V. Fig. 13, containing eight Betz cells which will be described in detail later when discussing this latter plate. To the left of this group opposite 14 are seen three Betz cells of small size and somewhat separated from one another. To the left of these at a short distance are seen two Betz cells, one above the other. Opposite 15 are seen two groups of two each, the cells in the first group being somewhat separated from one another and one above the other. Opposite 16 is a well marked group of four Betz cells, two being very large and the other two smaller in size. Below this and upon the anterior surface of the gyrus opposite 17 are two solitary Betz cells, one lower than the other and nearer the surface. Opposite 18 is still another smaller solitary Betz cell at a greater depth. For some distance below this no Betz cells are to be seen until opposite 19 is a solitary Betz cell. Just below this and slightly nearer the surface is a group of three of the intermediate sized cells. Opposite 20 are two large solitary Betz cells, the lower larger one being at a slightly greater depth. Then comes another region barren of these cells until the point opposite 21 is reached where a small solitary intermediate size cell is seen, and below this a group of two of these same cells is to be noted, one at a greater depth than the other. Opposite 22 is a very large solitary Betz cell. Just below this are two intermediate size cells, and still below this and at a slightly greater depth are three of these intermediate size cells. This includes all the Betz cells though, as above noted, here and there in different parts of this layer; but for the most part in the same relative position, are to be seen very large pyramidal cells approximating these Betz cells both in size and structure, and the writer thinks should be regarded as intermediate in type between the large pyramidal cells and the giant pyramidal or Betz cells,—a transition form, if they might be so called. There are twenty-eight groups of these Betz cells in all in this plate, varying in number from one to eight cells in each group, one to three being the usual number. Fourteen of these groups contain but one cell each, and these so-called solitary cells are usually of large size. There are eight groups containing two cells each, four groups of three cells each, but one group containing four cells, and one group containing eight cells. Taking the groups from the lower portion of the posterior surface in succession, as above described, and the number of cells in each of the twenty-nine groups is found to be as follows: 3, 1, 3, 1, 1, 1, 2, 1, 1, 1, 2, 2, 1, 3, 2, 1, 1, 2, 8, 3, 2, 2, 2, 4, 1, 1, 1, 1, 1, making a total of fifty-five Betz cells in the section, and thus averaging about two cells to each group. The number of groups is somewhat more than in Plate IV. Fig. 9, in which there were twenty-three groups containing in all fifty-nine Betz cells, and somewhat less than in Plate III. Fig. 7, where there are thirty-one groups containing sixty-one cells. It will thus be seen that the average number of groups and total number of cells in these three sections from near-by portions of the same block are fairly uniform in regard to the arrangement and distribution of the Betz cells. It is to be noted that more cells are found on the posterior aspect of the gyrus than on the anterior. In Plate III. Fig. 7, there are fifty cells arranged in twenty-five groups on the posterior aspect of the gyrus, with but four cells in two groups at the vertex, and seven cells in four groups on the anterior aspect. In Plate IV. Fig. 9 there are thirty-seven cells arranged in nineteen groups on the posterior aspect of the gyrus, fifteen cells in two groups at the vertex, and seven cells in two groups on the anterior aspect. Finally, in Plate IV. Fig. 11, there are twenty-seven cells arranged in seventeen groups in the posterior aspect of the gyrus, nineteen cells in six groups at the vertex, and nine cells arraned in six groups on the anterior aspect. It will thus be seen that most of the Betz cells are on the posterior aspect of the gyrus and gradually diminish in number upon approaching the vertex until upon the anterior aspect there are but few to be seen. Table III. shows the above results in tabulated form. Upon referring to this latter it will be seen that the average number of cells in each section is fairly uniform—55, 59 and 61 for the three sections; the grouping is somewhat more variable—23, 29 and 31, most of the cells singly or in groups of two or more being upon the posterior aspect and vertex. This corresponds to the findings of Lewis and Clarke ('78) who examined sections from various parts of the left anterior central convolution and the posterior portion of the two upper frontal convolutions on the same side in several human brains microscopically, and made diagrams of the distribution of the Betz cells at various points instead of employing photomicrographs showing the number, arrangement and relation to other elements of the cortex of these Betz cells as in this article. Plate V. Fig. 13 is a beautiful photomicrograph of a group of these Betz cells magnified 825 diameters and taken from the point marked *a* in Plate IV. Fig. 11. Here is seen a "nest," or group of these cells, eight

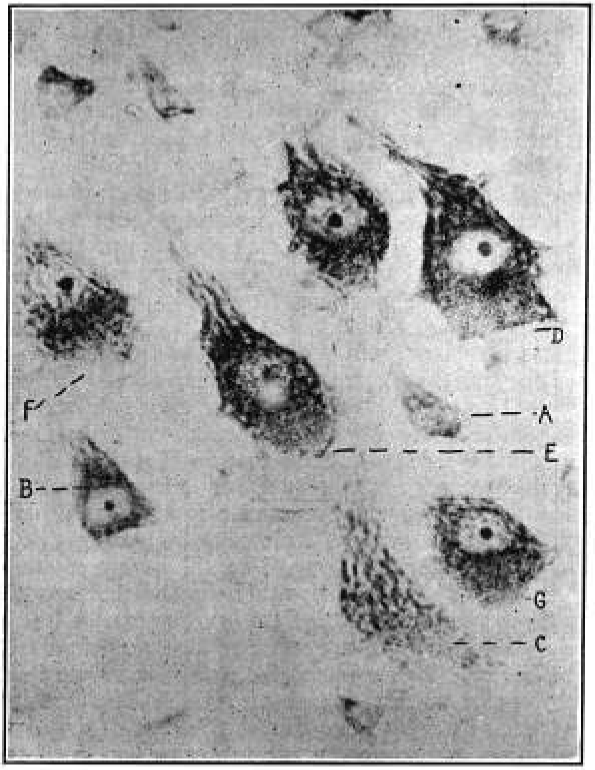

Plate V, Fig. 13

in number. All of these Betz cells contain pigment excepting the one marked *a* which in size is not much larger than one of the large pyramidal cells, but in structure resembles the Betz cells. This pigment, varying in amount, is situated at the base of the cell below the nucleus, excepting in the cell marked *b* where it is just above the nucleus. In the cell marked *c* it extends down into the large basal dendritic process, given off to the right for a short distance. In the cells marked *c, d, e, f* and *g,* the cell body appears of a lighter color in the photomicrograph where this yellowish pigmentary deposit is found. The cell marked *c,* sectioned outside of the plane of the nucleus, shows very well the general arrangement of the rounded or elongated chromophilic bodies in a direction parallel to the contour of the cell-body, thus classifying it with the others of similar type as stichochrome nerve cells of the somatochrome class. The cell marked *e* shows the general parallel arrangement of the chromophilic bodies in the apical process very well. The group, as a whole, is very compact and as each cell is cut in a somewhat different plane from the others most of the features of such a "nest" are thus brought out. Of course, there may be other cells in this group lying outside of the ones seen here —in the planes above and below this. Plate IV. Fig. 12 is a pho-

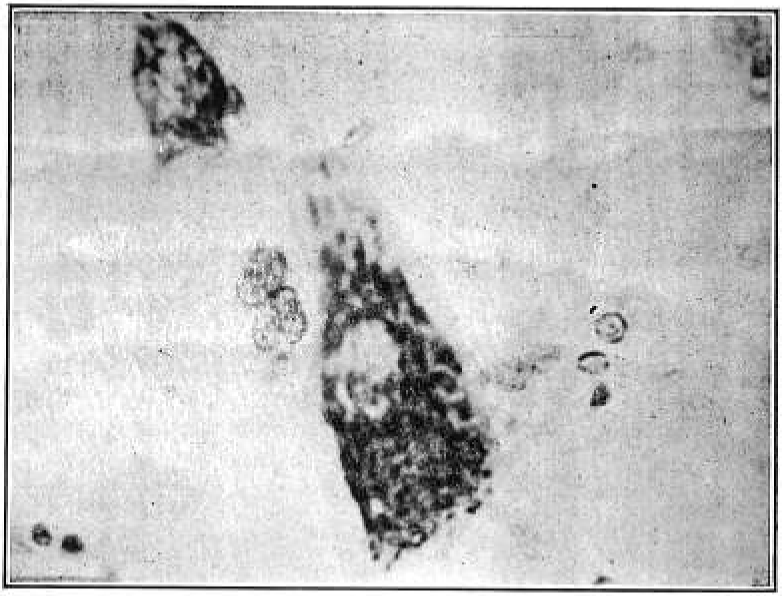

Plate IV, Fig. 12

tomicrograph of a Betz cell magnified 1,400 diameters from a section adjacent to and upon the same slide as that from which Plate III. Fig. 8 was taken. The section is, therefore, similar in shape to the one in Plate III. Fig. 7, and this cell is situated in a position opposite to the letter *d*, and in the lower portion of the second

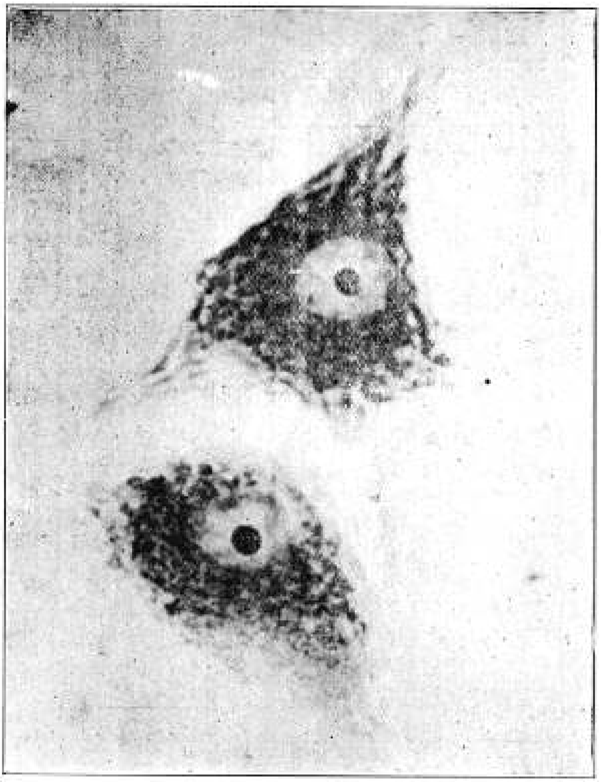

Plate V, Fig. 14

or pyramidal cell layer of this latter. The section is ten microns in thickness and stained with methylene violet. It can readily be appreciated from this photomicrograph that only an extremely thin plane can be seen under such a high magnification and not all of this even will be in sharp focus. The nucleus here is mostly below the plane of the section and the deeply stained nucleolus entirely so. Two dendritic processes are faintly seen coming off from the base of the cell, the one on the right but faintly shown as it is at a different level for the most part. The one on the left is somewhat more distinct and chromophilic bodies are found to enter the base and extend for a considerable distance into the same. These bodies of varying size and in general rounded or linear in shape, are closely packed in most parts of the cell-body, excepting at the base where a large deposit of yellowish pigment, taking up about the same area of space, as the nucleus, is to be found. These chromophilic bodies are arranged in general parallel to the contour of the cell-body and extend into both the basal dendritic processes and the apical process as far as they can be traced. A portion of another Betz cell smaller in size is seen above and to the left. About the larger cell are several neuroglia cells singly or in groups, and these are seen to be distinctly rounded or oval with usually a ring of chromatic substance of varying thickness at the periphery and several irregular deeply stained bodies in the center. Twenty neuroglia cells in all are seen in this plate. Plate V. Fig. 14, is a photomicrograph of the same magnification,—1,400 diameters,—as the preceding and taken from a section of the same block. The section of the same form and size as that seen in Plate III. Fig. 7, is ten microns in thickness, and stained with methylene blue instead of methylene violet, but otherwise treated in exactly the same way. One noticeable point about this plate is the absence of neuroglia cells, in marked contrast to Plate IV. Fig. 12, indicating again that the neuroglia cells do not retain the methylene blue stain with the same intensity as when similarly treated with methylene violet. Here is seen a group of two Betz cells, the upper one, at this plane broadly pyramidal in shape, and the lower one presenting an irregular spindle shape. This latter, however, is only the base of the cell, the process above and to the left and that below and to the right being basal dendritic processes, and the apical dendritic process extending upward beyond the base of the upper cell in a different plane. There are two other Betz cells just above and slightly to the right of these cells in the section, not shown in the plate, thus making the group consist of four cells in all. Both of these cells are cut in the plane of the nucleus and large, rounded, deeply stained nucleolus. The nuclear body also contains some chromatic substance arranged in an indefinite network. At the base of the lower cell and extending into the large basal dendrite to the right as far as it is seen in this section is a distinct mass of yellowish pigment displacing the other cell contents. In the plate it is of a lighter color than the rest of the cell. Above this in the cell-body about the nucleus, and extending into the other basal dendrite, are numerous rounded and linear chromophilic bodies. The upper cell shows three dendritic processes going off from the base of the cell-body on the right side, and two from the left side. These processes and the large apical process contain mostly linear-shaped chromophilic bodies, arranged in distinct striæ, parallel to the contour of the same. This arrangement also holds good at the periphery of the cell-body, the striæ there too being parallel to the contour of the same, but about the nucleus the chromophilic bodies are so closely packed that it is more difficult to make out this parallel arrangement. There is no pigmentary deposit in this cell. No neuroglia cells are to be seen in this plate, the methylene blue stain being used as stated above. Plate V. Fig. 15, from the same region and under the same magnification, 1,400 diameters, from a section ten microns in thickness and stained also with methylene blue, is an exceptionally fine photomicrograph of one of these

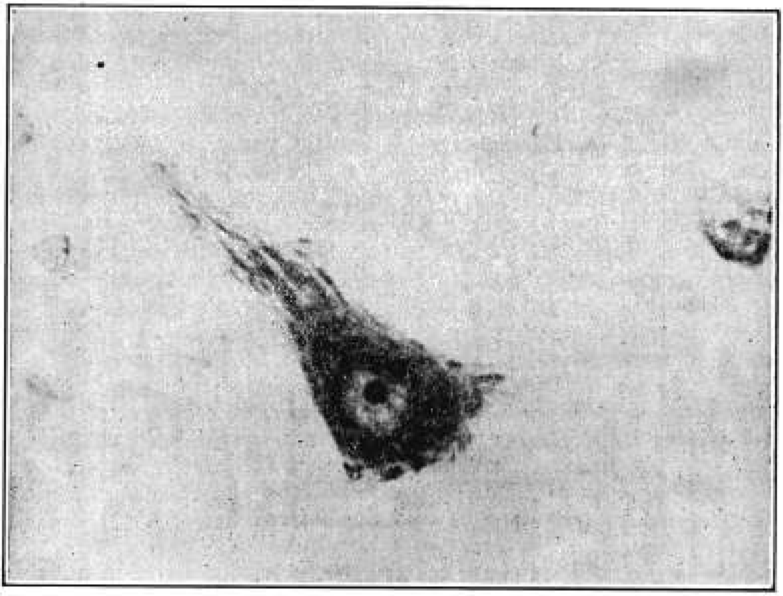

Plate V, Fig. 15

Betz cells, inasmuch as it shows the processes, especially the apical process, as far as the edge of the plate. It is usually difficult to obtain such an extent of surface of a cell in the same plane under such high magnification even when the microtome cuts in exactly the plane of the long axis of the cell. These dendritic processes are seen to be of no mean size, especially the apical process and the chromophilic granules extend far up into the same. Three processes are seen given off from the base, one at each angle, and the third descending from the center. The nucleus is distinct, centrally located, and contains a large nucleolus surrounded by an irregular chromatic network. The chromophilic granules are larger and smaller rounded and irregularly spindle-shaped granules in the triangular-shaped body of the cell, approaching to a more linear form in the processes. This is a stichochrome nerve cell of the somatochrome group.

Turning again to Plate III. Fig. 8, the third layer will now be described. This is but .70 mm. in thickness as compared to 1.20 mm. for the same layer in Plate II. Fig. 3. The nerve cells in this layer are similar in form and structure to those found in the above mentioned plate. The neuroglia cells are much more numerous in all the layers than in Plate II. Fig. 3, due in large part, the writer believes, to the difference in the staining method. Capillary vessels, showing the walls made up of a single layer of nucleated flattened cells, are seen in several places, especially in the lower layer. Counts were made of the nerve and neuroglia cells in different regions in the manner previously described, using the same method and magnification. Counts of the nerve cells in eight different fields from various portions of the second and third layer were made, each field containing thirty-six squares, so that 288 squares were examined. There were found to be an average of .95 nerve cells to each square millimeter of the ocular net-micrometer, which multiplied by 100 gives 95 as the average number of nerve cells found to the square millimeter in the second and third layer of the cortex in this section. The first layer contained so few scattered nerve cells that no field was included for this portion of the cortex, as some fields here would contain no nerve cells whatsoever and would thus greatly reduce the general average where the Nissl stain is employed. On this account the nerve cell counts in this and all subsequent sections, as well as that of Plate II. Fig. 3, include only the second and third layers of the cortex. The nerve cells are thus fewer in number than in Plate II. Fig. 3, but they average larger in size, especially in the region of the large pyramidal and Betz cells; thus the frontal convolutions seem to to contain more nerve cells than the central convolutions.

Neuroglia cell counts were made from three fields of thirty-six squares each or 108 squares in all from all three layers of the cortex. The average number of neuroglia cells was found to be 2.93 for each square millimeter of surface of the ocular net-micrometer, which multiplied by 100 gives 293 as the average number of neuroglia cells in each square millimeter of surface of the cortex from this section. The number in each square here varied from none in some squares to fourteen in one of the squares. The next highest number was eight, several contained seven, but most of them contained from one to four. Counts were also made from a section of the same thickness, ten microns, and from the same block as the preceding, but stained with methylene blue instead of methylene violet. With this exception the technique was exactly the same in the two preparations. Counts were made from six different fields of thirty-six squares each, and the average number of nerve cells to each square mm. of the ocular net-micrometer from various parts of the second and third layers was .94. This result multiplied by 100 gives 94 as the average number of nerve cells to each sq. mm. of surface of the section as compared to 95 in Plate III. Fig. 8, a remarkably small difference of only one cell to each square millimeter, both counts being made, the one entirely independent of the other. Counts were made from seven different fields of 36 sq. mm. each from various parts of all three layers of the cortex to determine the average number of neuroglia cells. The average number to each square millimeter of the ocular net-micrometer was found to be .84, which multiplied by 100 gives 84 as the average number of neuroglia cells to each square millimeter of the section as compared to 293 in Plate III. Fig. 8, where the methylene violet stain was the stain used. This further confirms the statement previously made that methylene violet has a greater affinity for these neuroglia cells and the latter retain this dye much more tenaciously than they do the methylene blue in the subsequent differentiation, whereas the nerve cells retain either dye about the same. The same fact is well

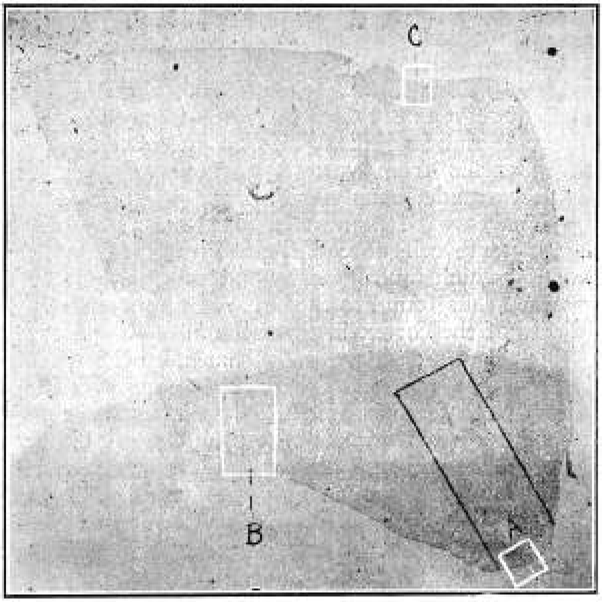

Plate VI, Fig. 16

brought out in Plate IV. Fig. 12, and Plate V. Fig. 14, previously described. In the latter two, Betz cells are seen under a magnification of 1,400 diameters. The stain used here is methylene blue, and no neuroglia cells are to be seen. In Plate IV. Fig. 12, of the same magnification, but stained with methylene violet, twelve of these neuroglia cells are seen in the immediate vicinity of this large Betz cell. Sections were also prepared from blocks taken from the middle and lower thirds of this same convolution,—the anterior central,—and it was found that the general type of cortical lamination and histological structure remained the same. Plate VI. Fig. 16, is a photomicrograph of a section taken from a block including the entire anterior central convolution for a distance of .4 mm. in its lower third and is representative of the entire lower portion of this convolution. The shape of the convolution is seen to have undergone considerable modification as compared to the upper third, seen in Plate III. Fig. 7. This section is ten microns in thickness, fixed in alcohol 95 per cent., stained with methylene violet, the other technique being similar to previously described sections. The segment of cortex shown in Plate VI. Fig. 17, under a magnification of 100 diameters, was taken from the point indicated by the ink lines here and opposite *a*. It is seen from the mechanical arrangement of the cortex to be at the most acute angle and where the same is thickest. At the opposite less acute angle the cortex is not quite so thick, and intermediate between these angles, and also on the anterior and posterior surfaces the cortex is still thinner. It will be noted that the depth of the sulcus anteriorly at *c* where it passes over into the third frontal convolution and is thus adjacent to the motor speech area, is more shallow than the posterior sulcus or fissure of Rolando. The first layer is irregular in depth, somewhat thicker at the angle opposite *a*, and still thicker at *b* and *c*, whereas at the vertex it is thinner. The general radial direction of the cells from the medullary central white substance to the surface is fairly well seen here. In the second layer the most noticeable feature is the entire absence of the Betz cells which are so marked in the upper portion of the convolution. Some very large pyramidal cells, intermediate in size to the Betz cells and the ordinary larger pyramidal cells, are to be seen in this layer however, as will be noted in the following (Plate VI. Fig. 17): This layer merges into the third or irregular cell layer, which latter is gradually lost in the white central substance of the gyrus. At the vertex in the cortical layer the section is cracked; this being an artefact resulting from manipulation. The outer layer is seen to be also torn in places from the same cause. Plate VI. Fig. 17, is taken from the strip indicated in ink in Plate VI. Fig. 16, and is magnified 100 diameters. The first layer is .25 microns in thickness and similar in structure to the same layer in the upper portion of the convolution already described. In the second layer, however, the greatest difference is found. The large Betz cells practically disappear in the lower third of this convolution, although large pyramidal cells simulating them in general structure, but lacking the size, are found in the middle portion of this layer. In this lower third of the convolution the second layer as seen in this section is 1.50 mm. in thickness, and the large pyramidal cells are seen arranged in irregular groups in its middle portion. Below them is seen a region *a* averaging .25 mm. in thickness in which small pyramidal cells are almost exclusively found. Below this larger pyramidal cells are seen, but not in great numbers. The divison between this and the lower or spindle cell layer is not well marked, the latter measuring .90 mm. in thickness. The cells here are irregularly polygonal or spindle shaped and do not differ from those in the same region in the upper part of this convolution. The total thickness of the cortex at this point is 2.65 mm., exactly the same as of the section shown in Plate III. Fig. 8. Counts of the nerve and neuroglia cells were made in this region in exactly the same manner as in the previously described regions. This section, as above stated, is ten microns in thickness and stained with methylene violet and in seven fields of 36 sq. mm. each from various portions of the second and third layers, the average number of nerve cells to each square millimeter of surface of the ocular net-micrometer was found to be 1.08, multiplied by 100 gives 108 as the average number of nerve cells to each square millimeter of surface of the section in the second and third layer. The nerve cells in the first layer were so few and scattered that no counts of the same were made. In eight fields of 36 sq. mm. each from various portions of the three layers of the cortex in this section the average number of neuroglia cells to the square millimeter of surface of the ocular net-micrometer was 2.48, multiplied by 100 gives 248, as the average number of neuroglia cells to each square millimeter of surface of the cortex of this section. Here again it will be seen that the methylene violet stain shows a larger number of neuroglia cells—248, while the nerve cells—108, are but slightly in excess of the average number in the two previously described sections of the upper portion of the anterior central convolution, and slightly less in number than in the sections described from the frontal convolution (Table II.).

Passing now to the region posterior to this, we come to the posterior central convolution of this central or motor region. This posterior central convolution is regarded as a transition region between that anterior to the fissure of Rolando, or motor region, and that posterior to the same region, or sensory region of those authors who divide the cortex into a sensory and motor type of cortical lamination. The first and third layers here are practically the same as in the region anterior to the fissure of Rolando. The second layer, however, lacks the regularity of the corresponding layer in the above mentioned region, but as will be seen in the plate (Plate VII. Fig. 19), there is nothing new or different in this layer from the corresponding layer in the plates already described. The large Betz cells seen only in limited portions of the region just anterior to this and contained in but a very small portion of this so-called motor region are replaced here by some smaller sized, irregularly situated pyramidal cells, singly or in groups, and of similar internal structure, and mostly to be found in the middle and lower portion of the layer. As typical of this posterior central convolution, a section was taken from a block including the middle portion of this convolution in its entirety for a distance of 4 cm. (5, Plate I. Fig. 1). The section is 6 2-3 microns in thickness, fixed in 95 per cent. alcohol, and stained with methylene blue, technique otherwise similar to all other sections. Plate VI. Fig. 18, is a photomicrograph of this section, magnified 14 diameters. The convolution here presents a peculiar mechanical formation, causing a great variation in thickness of the cortex in different portions, being over twice as thick at *b* as at the point *a*, from which latter point Plate VII. Fig. 19 was taken. This condi-

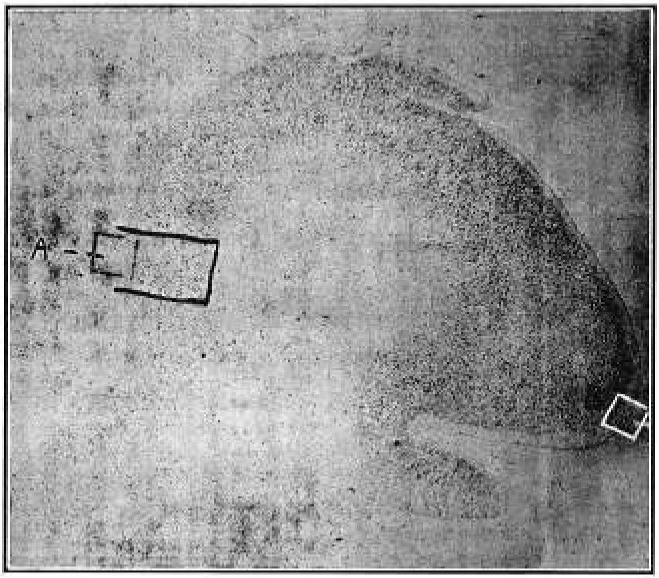

Plate VI, Fig. 18

tion is not an artefact, as under high magnification no indication of disturbance of the relations of the cells is to be observed. At the vertex, however, there is an artificial break in the first and upper part of the second layer at two points. The first layer is seen to vary in thickness, being thicker at the acute angle below *b*, and gradually becoming thinner as it approaches the vertex, to become again thicker below *a*. The general radial direction of the cells is well seen, especially at the vertex and anterior aspect, as at *a*. At *b* it is not quite so well made out, but exists to a fairly well marked degree when examined under a higher power. Pyramidal cells of considerable size are seen in some parts of this layer, more especially in the middle portion, but in no case do they approach in size to the Betz cells, nor are they for the most part situated in the same portion of the cortex. The third layer is thin and soon lost to view in the medullary white substance. Plate VII. Fig. 19, is a photomicrograph of the strip *a* enclosed in ink lines in Plate VI. Fig. 18, and magnified 100 diameters. The first or upper layer at this point is somewhat irregular in contour and averages .20 mm. in thickness. It contains neuroglia cells and some scattered nerve cells similar in appearance and structure to those described in Plate II. Fi. 3, for the same region. The second or pyramidal cell layer is especially interesting, owing to the irregularity of the distribution of its cells. At the upper portion the small pyramidal cells are seen closely aggregated together. Below this these cells become more scattered, and irregularly interspersed among them are medium sized and larger pyramidal cells. Some of the larger of these have a tendency to be arranged singly or in groups and have an internal structure similar to the giant pyramidal or Betz cells found in parts of the anterior central convolution and in the posterior part of the first frontal convolution. The chromophilic granules are, however, of smaller size though similarly arranged in some of the cells. About the middle of this layer, opposite *a*, is seen another region in which the small pyramidal cells predominate, and in which there are scarcely any larger pyramidal cells. Just below this again are seen large pyramidal cells arranged singly and in groups, forming the lower portion of this second layer which measures about 1.45 mm. in thickness and below gradually merging into the third or spindle cell layer. In addition to the spindle cells there are many irregular polygonal cells founds in this layer which at this point is about .60 mm. in thickness and only partially shown in the plate; the upper two-thirds being seen here. The lower third, not shown, is similar and gradually merges into the white medullary substance. The entire cortex is thus 2.25 mm. in thickness at this point, whereas, as above mentioned at point *b* in Plate VI. Fig. 18, it is over 5 mm. in thickness. Taking into consideration the variations found in different parts of the same area, often quite near together, and considering the general type of arrangements, it does not seem to the writer that this area varies to a very marked degree from the general type, or at least to such an extent as to be especially marked off from the other regions of the cortex. There is certainly a greater variation between different regions of the anterior central convolution as in the upper and lower portions, where some parts have no Betz cells and others have them variously distributed, as well as other differences, than between this region and the frontal region as a whole. Those who separate the cortex into two types,—an anterior or motor type, and a posterior or sensory type,—regard this convolution as the transition region between the two. An examination of sections, both anterior and posterior to this convolution, shows that the same general plan of arrangement is carried out in all parts of the external surface of the cortex with only minor differences which do not seem sufficient to make such a marked distinction applicable anatomically, and certainly not histologically. The size and form of the cells and their general arrangement differs but slightly from that of the region anterior and posterior, with the exception of the Betz cell groupings in localized portions of the former.

Nerve cell and neuroglia cell counts were made with the ocular net-micrometer here in this region in the same manner as in the other previously described sections. Eight fields of thirty-six square millimeters each, from various portions of the second and third layers of the cortex, were examined and 185.5 nerve cells were found to be the average number for each square millimeter of surface of the section. In the same manner the neuroglia cells were counted in eight fields from all three layers of the cortex and 109.2 neuroglia cells were found to be the average number for each square millimeter of surface of the section in the cortex. Here methylene blue was the stain employed with the resulting low average number of neuroglia cells, whereas the average number of nerve cells is found to be higher than in any of the previously described sections anterior to this region, and it will be seen subsequently that it is also higher than that found for the region posterior as well although the section is 6 2-3 microns in thickness, and some already described are 10 microns in thickness (Table II.). This, however, bears out the statement previously made that sections between six and ten microns in thickness contain practically all nerve cells that can be seen in one plane.

Parietal Region.—Posterior to the region just described we come to the parietal region, made up of the superior parietal, supra-marginal, and supra-angular convolutions. The general arrangement of the layering of the cortex is fairly uniform throughout this region and the section represented in Plate VII, Fig. 20, from a block taken from the supra-marginal convolution is typical of this region (7, Plate I, Fig. 1). The block was fixed in Van Gehuchten's fluid, stained with methylene violet, and other technique as for previous regions. The actual size of this section is 7 mm. in its greatest width, and 8 mm. in length, and it is 6 2-3 microns in thickness. As seen in the photomicograph, magnified 14 diameters, the convolution is wider above at the surface than deeper down in the sulcus. At the point *a* is seen the position of the strip from which the photomicograph represented in Plate VII, Fig. 21 was taken. At *b* and *c*, owing to the greater angle, the cortex is considerably thicker than at *a*. The shape of the convolution here is seen to be different again from any of the preceding, thus giving a somewhat different mechanical arrangement, with a broad flattened vertex and shorter anterior and posterior aspects. At the lower portion, on the right, a part of the cortex was cut away in removing the block. In the vicinity of *a* there are some minute artefacts, causing an irregularity of the surface here, and small fragments are partially torn away at two points. The first, or superficial layer, is fairly uniform in thickness, excepting opposite *a*, which will be discussed more fully in describing the next plate (Plate VII, Fig. 21), and upon

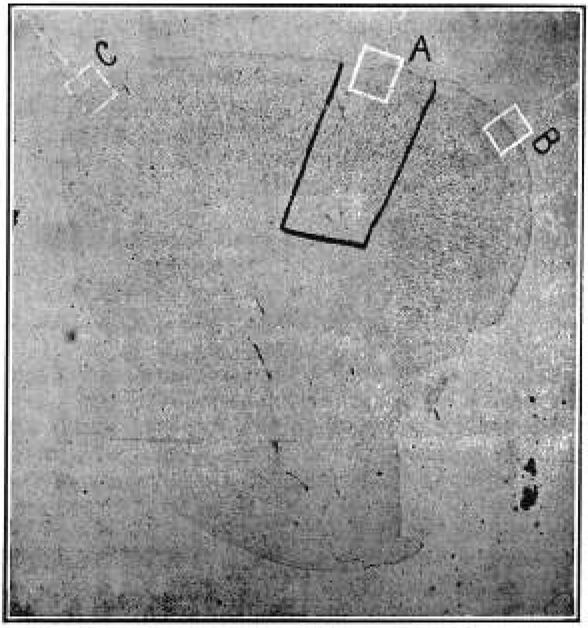

Plate VII, Fig. 20

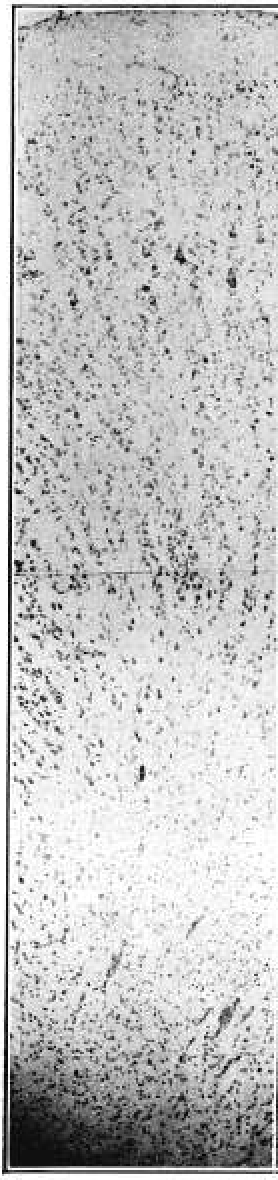

Plate IX, Fig. 25.

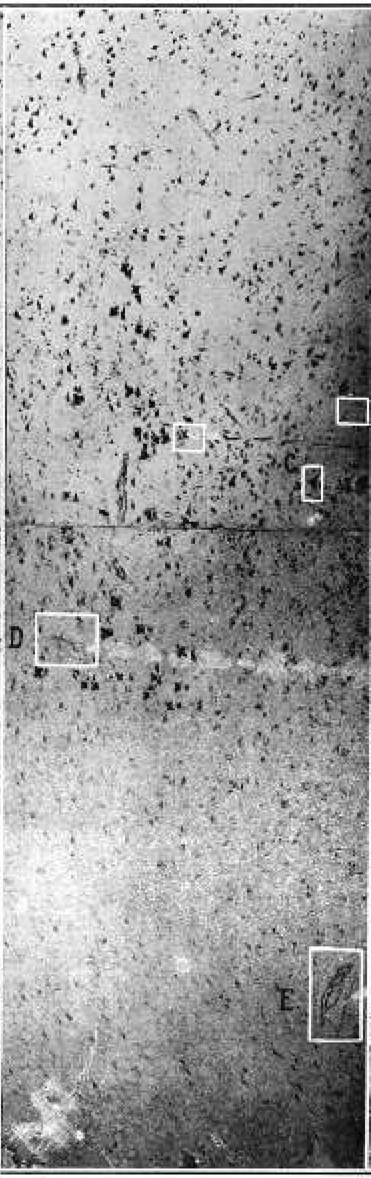

Plate XI, Fig. 31.

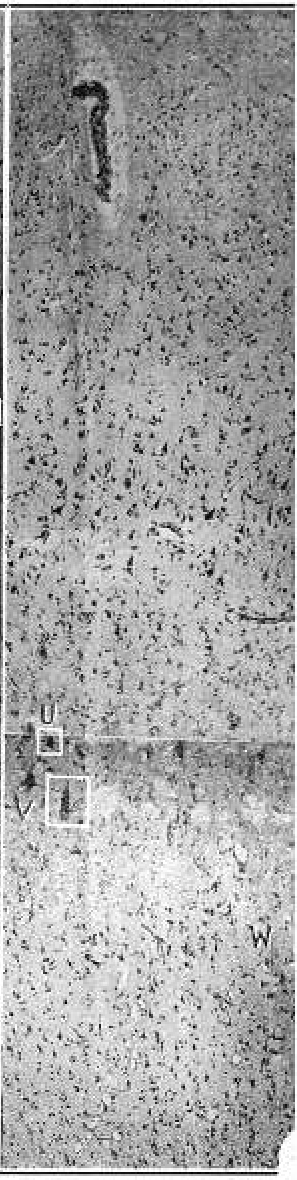

Plate XI, Fig. 33

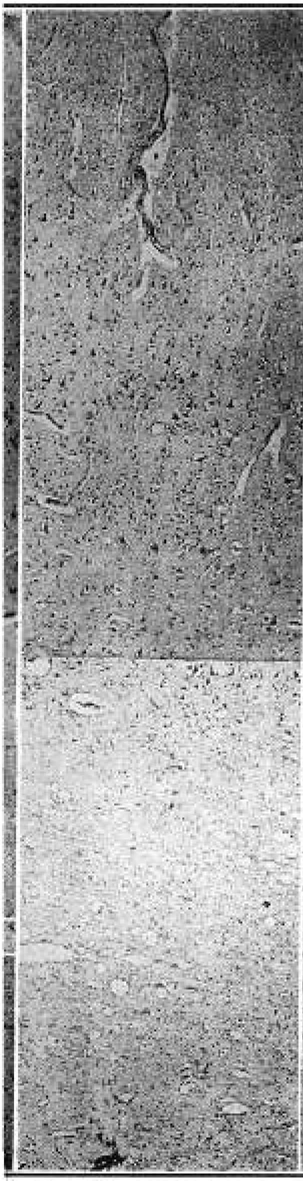

Plate XIV, Fig. 43.

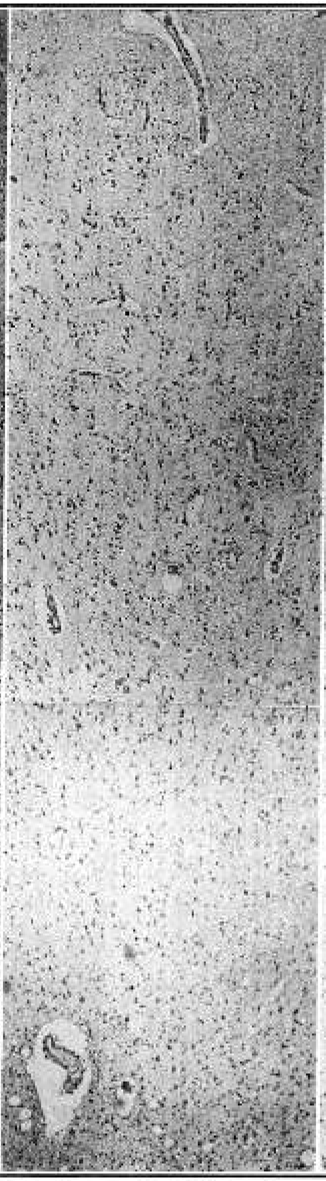

Plate XV, Fig. 45.

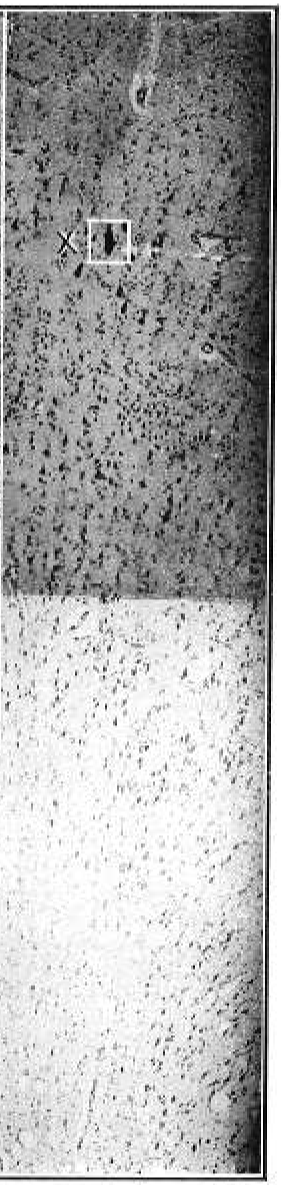

Plate XV, Fig. 47.

the posterior and anterior aspects, where this layer is slightly thicker. The radial arrangement of the cells of the second layer is well shown, and the cortex is seen to be thicker at the angles *b* and *c*, as before mentioned. Throughout the middle and lower part of this layer well developed pyramidal cells are seen, some almost approaching in type small Betz cells. The third layer presents nothing unusual, and gradually passes over into the white medullary substance. Plate VII, Fig. 21, shows the strip indicated in ink opposite *a* in Plate VII, Fig. 20, under a magnification of 100 diameters. The first or superficial layer is seen to be irregular at this point, about 20 mm. in thickness at the right of the plate, then increasing rather suddenly to .25 mm. for a short distance, when the outline suddenly descends, decreasing the layer at this point to .15 mm. It then gradually increases until, at the left of the plate, it is .22 mm. in thickness. The extreme thickness near the center, although the surface is only slightly torn at several points and scarcely noticeable, yet has the appearance of an artefact, due no doubt to the unequal pressure in the manipulation of removal, when the brain was in its natural soft condition, prior to any post-mortem changes. A short distance below the surface at this point the cortical substance itself is seen slightly broken, thus confirming the artificial nature of the irregularity and increase in depth. The nerve and neuroglia cells are similar to those found in this layer in the regions anterior to this. The second or pyramidal cell layer is 1.60 mm. in thickness, and contains small pyramidal cells exclusively in the upper portion. Very soon, however, larger pyramidal cells appear, and at about the middle of the layer are the greatest in size and most numerous of the layer. Some of these large pyramidal cells in point of size and structure appear intermediate between the large and giant pyramidal or Betz cells. They also tend to be arranged singly or in groups, with smaller cells about them. Just below the middle of this layer, at *a*, is found a region .20 mm. in thickness, conspicuous by the almost entire absence of large pyramidal cells, and made up for the most part of small pyramidal cells. Below this large pyramidal cells again appear, intermingled with the small pyramidal cells, and the layer gradually passes over into the lower or spindle-cell layer. The pyramidal cells have the same internal structure as those in the region anterior to this, in the largest ones the chromophilic granules simply being larger and more conspicuous; thus these cells come under the same classification, according to Nissl, as those in the frontal and central convolutions. The third or spindle-cell layer is .70 mm. in thickness, and not distinctly separated from the layer above. The arrangement of the cells and their form and size, as well as the internal structure, is in no way different from the corresponding layer in the cortex anterior to this. The total thickness of the cortex here is then 2.50 mm., being .25 of a mm. thicker than in the section of the posterior central convolution previously described, .15 mm. less in thickness than the section shown in Plate III, Fig. 8, from the anterior central convolution, and .35 mm. less than in the section of the first frontal convolution shown in Plate II, Fig. 3. The variation in thickness is thus seen to be slight and no greater, and even not so great as can be found in contiguous portions of any one convolution. In other parts of the parietal region the arrangement of the cortical lamination is similar to that described above with minor modifications, due to differences in shape, etc., of the convolutions. Here nerve cell and neuroglia cell counts were made in the same manner as in previous regions, and the average number of nerve cells to the square millimeter of surface of the section was found to be 104, whereas the average number of neuroglia cells for the same area of surface of the section was 180.90. This is the lowest average of nerve cells in any region of this brain, with the exception of the upper portion of the anterior central convolution. The methylene violet stain makes the average number of neuroglia cells quite high, however, though considerably less than in the upper portion of the anterior central convolution.

Temporal Region.—Below the parietal region just discussed we come to the three temporal convolutions—the first, second and third. Here the general arrangement of the cortical laminations and the cell structure is practically the same in the three convolutions, and bears a striking resemblance to that found in the frontal region. A block was taken from the anterior portion of the first temporal convolution near the apex (6, Plate I, Fig. 1), the entire width of the convolution and for a distance of .4 cm. The actual size of the section from this block represented in the photomicrograph (Plate VII, Fig. 22) is 8.5 mm. at the widest point, and 8.5 mm. in length on the right, and 6 mm. in length on the left, and it is 6 2-3 microns in thickness. The block was fixed in Van Gehuchten's fluid, stained with methylene blue, all the other details of technique being similar to that employed for previously described sections. This photomicrograph is magnified 14 diameters, and here the shape of the gyrus is seen to be somewhat similar to that in Plate VII, Fig 20, but broader above, and also with a broader base. The vertex is flattened similarly, resulting in the more acute angle at *b* and the slightly obtuse angle at *c*, at which points the cortex is thicker than at the vertex or the anterior or posterior aspects. The cortex is seen to be uniformly thicker along the surface, opposite *d*, than upon the opposite aspect at and above and below *a*. The first or superficial layer is thicker at *c* than in other portions, and is somewhat broken in places along the vertex. The second layer varying in thickness, being thickest at the points mentioned above, where the entire cortex is thickest, shows the radial arrangement of the cells very well, especially at the vertex and opposite *a* and *b*. The larger nerve cells appear quite conspicuous in the middle and lower portion of this layer in places. The third layer is quite uniform, disappearing in the white medullary central substance. Plate VIII, Fig. 23, shows the strip *a* of Plate VIII, Fig. 22 at a magnification of 100 diameters. Here the differentiation has been carried to about the same stage as in Plate II, Fig. 3, and the paucity of neuroglia cells is equally as apparent. Again the general arrangement of the cells in the two plates is remarkably similar. The first or superficial layer is here .25 mm. in thickness, and contains, for the most part, neuroglia cells and a few scattered nerve cells. The second or pyramidal cell layer measures 1.65 mm. in thickness, as compared to 1.40 mm. in Plate II, Fig 3, being thus slightly thicker than in the latter. The cells are arranged practically the same, however, the small pyramidal cells above intermingled with larger pyramidal cells in increasing numbers deeper down in the layer. Here again, at a point somewhat deeper than in Plate II, Fig. 3, is to be found a region at *a*, of the same thickness—.30 mm., where small pyramidal cells are found almost ex-

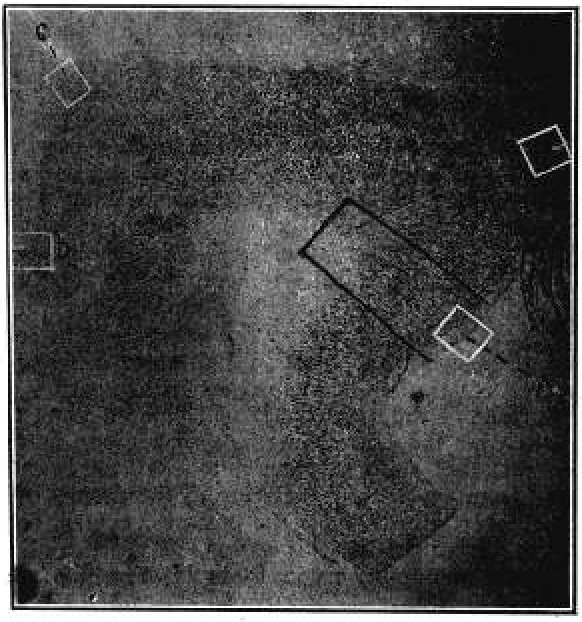

Plate VII, Fig. 22

clusively, followed again by a region containing large pyramidal cells in considerable numbers in addition to small pyramidal cells. This layer finally passes over into a narrow (.40 mm. thick) third or spindle-cell layer. This layer is also similar to that of Plate II, Fig. 3, with the exception of its depth, the latter having a spindle or irregular cell layer, measuring 1.20 mm. in thickness. As will be seen by referring to Plate I, Fig. 2, the strip *a* represented in Plate II, Fig. 3, was taken from the point of greatest curvature, where the cortex is usually the thickest, whereas Plate VIII, Fig. 23, was taken from the point *a* shown in Plate VIII, Fig. 22, from the side of the section where the cortex is thinner. The entire depth of the cortex is found to be 2.30 mm., as compared to 2.85 mm. in Plate II, Fig. 3, a difference of .55 mm. There are no larger pyramidal cells here intermediate in size between the Betz cells and the ordinary large pyramidal cells, as were noted singly or in small groups scattered in the central and parietal convolutions already described, and, as we shall see, also occur in the occipital convolution. The internal structure of these cells and their classification are similar to that for the cells described in Plate II, Fig. 3. Nerve and neuroglia cell counts were made from this section, which, as above mentioned, is 6 2-3 microns in thickness and stained with methylene blue. Seven fields of 36 sq. mm. each gave an average of 146 nerve cells to each square millimeter of surface of the section, and eight fields of the same size gave an average of 131.90 neuroglia cells to each square millimeter of surface of the section. It will be seen upon comparing these figures with those from sections of regions more anterior and above, that they show a larger number of nerve cells than in the sections from the regions anterior to the fissure of Rolando, but a less number than that for the posterior central convolution, and more than from the parietal region. The neuroglia cells are about the same in number as in Plate II, Fig. 3 of the frontal region.

(*To be continued.*)